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Effect of nitrogen source and acclimatization on specific growth rates of microalgae determined by a high throughput in vivo microplate autofluorescence method

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Iodine in seaweed - occurrence, speciation, bioavailability and risk assessment

General information
Microalgae biorefinery symbiosis: screening, production, and process analytical technology

Microalgae treatment of municipal wastewater (WW) has been the focal point of microalgal biotechnology research for several decades. However, this technology did not have a competitive advantage over other WW treatment technologies, which could be implemented in smaller areal footprints. In the past few decades, microalgal WW treatment has made a resurgence with the idea of using biomass from microalgal WW treatment, as a source of lipids for conversion into biodiesel. However, the savings from the treatment of nutrients and organic matter, as well as biodiesel production, are still not competitive with the price of crude oil. In recent years, microalgal research continued with the prospect of a microalgae biorefinery, where microalgal byproducts and coproducts are extracted to valorize the entire microalgal production, in which the sum of the parts of the microalgae is greater than the whole microalgae. However, in large part, the microalgae biorefinery does not comply with the treatment of nutrient-rich municipal WWs, due to regulatory concerns. Only recently, it was realized that bioindustrial WWs are viable and conceivably regulatory compliant nutrient rich waste streams, capable of sustaining microalgal growth, as much as municipal WWs. The concept of an “industrial symbiosis” has also emerged in the past several decades, in which networks of industries cooperate to use waste sources from neighboring industries, in industrial parks, to create added value. The intersection of the microalgae biorefinery and industrial symbiosis, in a microalgae biorefinery symbiosis (MBS), may be the next generation scheme to valorize the microalgal production and promote industrial and global sustainability. Moreover, technological advances in screening, outdoor photobioreactor (PBR) design, macromolecular monitoring and process automation must all be addressed to execute the complex bioprocesses needed to valorize an MBS successfully.

In order to properly identify viable MBS partnerships with industry, microalgal species capable of producing an array of valuable products must first be screened on these potential bioindustrial WW streams for their growth potential. During screening, microalgae may have a preference or aversion for a given bioindustrial WW media, based on the types and ratios of nitrogen (ammonium, nitrate, or urea) in the WW. Furthermore, identifying algae capable of withstanding fluctuations between these nitrogen forms in dynamic WWs, is an important criterion for productivity. However, when screening microalgae on WWs containing different nitrogen sources and concentrations, assimilation of different nitrogen sources can result in starkly different physiochemical changes, specifically pH changes. In many microalgae, ammonium is the preferred nitrogen source, because it can passively transport into the cell and is directly assimilated into amino acids, without relying on light-mediated enzymatic processes to be reduced. However, when microalgae assimilate ammonium, the pH of the system can drop sharply, inhibiting growth after that; however, these pH changes do not directly reflect the microalgae’s affinity to grow on ammonium. By growing batch cultivations of microalgae in 24-well microplates, a microplate reader can be used to measure relative fluorescence of chlorophyll in vivo, during balanced growth, before these pH changes occur. This technique can be used to preempt the effects of pH changes on growth and reflects the true preference or aversion of microalgae to a particular nitrogen source or a WW media. Additionally, along with being spatially high-throughput in a 24-well microplate—where 24 batch reactions can be conducted simultaneously in a small footprint—the early and low detection of growth rates is also more temporally high-throughput than any other screening method. This method can also be used to quickly screen for robust and adaptable microalgae, capable of acclimatizing to different nitrogen sources and fluctuating media as well as to screen for the upper and lower tolerances of the microalgae to various concentrations of the WW. The latter must also be addressed when screening dynamic WW capable of large fluctuations.

Over the years, there have been very few demonstrations of outdoor microalgal growth in enclosed PBRs; demonstrations, which are essential for understanding the feasibility of an MBS as a whole. From microplate scales to large-scales—six orders of magnitude larger—the industrially important screened microalgae Chlorella sorokini was grown on bioindustrial WW, inside a novel, solar tracking, 4000 L, airlift PBR. Despite cold temperatures and low irradiance, the microalgae reached a growth rate of 0.48 day⁻¹ , in the four-day period immediately following inoculation of bioindustrial WW containing ammonium, as a primary nitrogen source. After that, after ammonium was depleted and the media was augmented with nitrate, a long lag phase persisted, before undergoing the predominant production phase with a specific growth rate (SGR) of 0.15 day⁻¹ over an 18-day period. It was evident that the transition from ammonium to nitrate metabolism can severely stunt microalgal growth in the outdoor PBR under low temperature and irradiance. More importantly, the delay in growth did not appear to be due to deleterious effects of the contents of bioindustrial WW media,
since rapid growth was observed early in the experiment on the unaugmented WW. Moreover, it was demonstrated that microalgae could continue to grow in adverse environmental conditions at large-scales. The success of the in vivo fluorescence microplate assay and the complexity of these outdoor reactions demonstrate the value of pursuing real-time data of microalgae “in vivo at large-scales. The complex and dynamic nature of large-scale outdoor microalgal reactions, when grown on dynamic WW media, encourages the need for on-line, real-time monitoring to improve automation models of PBRs. In outdoor conditions with fluctuating light and temperature, there are several factors that can change the growth of microalgae, at time-scales less than a minute and as low as microseconds, which may not be accounted for in microalgal productivity models. Similarly, fluctuations of WW media are not accounted for in these models, especially in outdoor conditions. However, recent advances in hardware and software can significantly improve microalgal bioprocess models and automation, by manipulating large, time-resolute data sets, so-called “big data,” which can be acquired through high-selectivity vibrational spectroscopy, such as mid-infrared (MIR), near-infrared (NIR), or Raman vibrational spectroscopies. These large, real-time data sets can now be used to create adaptive models from artificial intelligence/machine learning tools or “black-box” models, to automate large-scale, outdoor PBRs treating WW.

With microalgae, now entering into a new paradigm of food, feed, pharmaceuticals and functional products, on top of biofuels in a biorefinery, there will be a growing need to maintain product quality, regulate, and mitigate contamination, especially in a symbiosis with WW. Vibrational spectroscopies can be used to monitor several microalgal components simultaneously, which can be used to aid fractionation of microalgal compounds in a biorefinery, while improving model building for automation and control of product quality and contamination, where quality can be built into the system. The results and research summarized in this thesis demonstrate that the modernization of microalgal research is becoming increasingly necessary and beneficial to microalgae production in an MBS. The focus of this thesis is to bring together lab-scale demonstrations, scaled up knowledge, and a critical outlook of modern technologies capable of making the MBS a reality.
Bioremediation capacity, nutritional value and biorefining of macroalga Saccharina latissima

Macroalgae have the ability to assimilate and convert waste nutrients (N and P) into valuable biomass. In this context, they have been extensively studied for their bioremediation potential for integrated multi-trophic aquaculture (IMTA). With a global aquaculture production of 23.8 million tonnes in 2012, macroalgae are a valuable source of vitamins, minerals, lipids, protein, and dietary fibres. Macroalgae have been used as food since ancient times in Asian countries, while in Europe they have lately been introduced as healthy food. Moreover, recently macroalgae have been receiving increasing attention as sustainable feedstock for biorefinery. Nevertheless, macroalgae resources are still very little explored in western countries. The aim of this study was fulfilled by the investigation of the bioremediation potential of the macroalga Saccharina latissima cultivated at a reference site (control) and at an IMTA site during 12 months (May 2013-May 2014), and assessing the effect of cultivation site and harvest time. Moreover, a comprehensive chemical and nutritional characterization of the produced biomass was made, and its potential as food and/or feed discussed. Finally S. latissima biomass was tested as feedstock for fermentation-based succinic acid production in a biorefinery approach. Maximum biomass yield over one growing season was achieved in August (1.08-1.51 kg fresh weight (FW) m-1 of cultivation line) and September (0.92-1.49 kg FW m-1). Biomass yield directly correlated with the nutrient removal which similarly peaked in August (5.02-7.02 g N m-1 and 0.86-1.23 g P m-1) and September (4.73-7.24 g N m-1 and 0.83-0.96 g P m-1). Moreover, both biomass yield and nutrient removal were higher in the IMTA site compared to the reference site in August (p<0.05). Additionally, macroalgal cultivation over two growing seasons enhanced the biomass yield and thus value, but not the bioremediation capacity. Harvest time had a significant impact in overall chemical composition, while cultivation site did not generally result in marked differences. The growth of epiphytic organisms from July to November makes the biomass unsuitable for human consumption, thus biomass meant to be used as food should be harvested in May. Protein content increased significantly from 1.3% dry matter (DM) in May to 10.8% DM in November. Similarly, the maximum essential amino acid (EAA) score was found in November (68.9%). Thus, results suggest an apparent mismatch between harvest time for human consumption (May) and the highest nutritional value of the protein in the biomass (November). The growth of epiphytes did not change the amino acid content or EAA score. However, the protein content and composition did not comply with the requirements for standard protein ingredients for fish feed (i.e. fishmeal, soymeal). The lipid concentration varied from 0.62%-0.88% DM in July to 3.33%-3.35% DM in November (p<0.05). Polyunsaturated fatty acids (PUFA’s) made up more than half of the fatty acids with a maximum in July (52.3%-54.0% fatty acid methyl esters). This including the most appreciated health beneficial PUFA’s, eicosapentaenoic (EPA; 20:5n-3) and docosahexaenoic acid (DHA; 22:6n-3), but also arachidonic (ARA) and stearidonic acid (SDA). Season of harvest is important for the choice of lipid quantity and quality, but the macroalga provides better sources of EPA, DHA and long-chain (LC)-PUFA’s in general compared to traditional vegetables. Regarding safety regulations, however, the main conclusions on the mineral analyses showed that high concentrations of iodine (up to 5,001 mg kg-1 DM) in the biomass may be of concern for human consumption, while the concentrations of total arsenic (up to 63.3 mg kg-1 DM) may restrict utilization as ingredient for feed. Seasonal variations in the content of carbohydrates, and fermentable sugars, had a significant impact on the succinic acid yield and titer. A maximum succinic acid yield of 91.9% (g g-1 of total sugars) corresponding to 70.5% of the theoretical maximum yield was achieved; while succinic acid titer amounted up to 36.8 g L-1 with maximum productivity of 3.9 g L-1 h-1. The high content of total phenolic compounds in the macroalga (July-August: 5-1% DM), and high concentration of inorganic nutrients in the solid residue recovered after enzymatic hydrolysis, makes co-production of antioxidants (i.e. phenols) and fertilizer very attractive. This was demonstrated to have the potential to increase the cost-effectiveness of the biorefinery facility. This study gives comprehensive information of the bioremediation potential of S. latissima cultivated commercially in the inner Danish waters. Year-round data show that harvest time can be effectively used to optimize the bioremediation capacity, and the biomass yield and application/value. The macroalga can be a source of valuable proteins, specific amino acids and food; however, high concentrations of iodine and total arsenic may be of concern regarding food and feed safety regulations, respectively. On the other hand, S. latissima is a promising feedstock for fermentation-based succinic acid production with co-production of phenols, and fertilizers.

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Cultivation of microalgae in industrial wastewaters

Microalgae production for the purpose of clearing wastewater has been researched for at least half a century. Such systems have a dual benefit: first, they prevent nutrients from entering water bodies and causing eutrophication; second, they transform sunlight and carbon dioxide into a biomass that has many potential uses. Unfortunately, the current high costs of cultivation have limited the development and exploitation of such systems, resulting in only a few full-scale algae wastewater treatment installations and a small industry based mostly around food and pigments. This thesis contributes to a growing body of knowledge with the aim to make algae cultivation viable for the production of sustainable products. Specific contributions include: improvement in the methods of screening the growth potential of different microalgae species; identification of an industrial wastewater that allows good algae growth; knowledge about the mixotrophic utilization of chemical energy present in organic waste; demonstration of a method to optimize efficiency of culture growth and nutrient removal; and biochemical characterization of the produced biomass.

When designing algae cultivation, one challenge is that there are many potential combinations which must empirically screened. Tens of thousands of microalgae species have been identified so far and there are numerous waste-streams that potentially could be of interest. A screening system was developed using the microplate as cultivation vessel and measurement cuvette. Fluorescence was demonstrated to be an order of magnitude more sensitive than optical density for detecting biomass growth, which increased the length of time in which exponential growth was observable from hours to days. This enabled growth rate-light intensity (µ-I) curves to be measured in microplates which were found to be equivalent to those obtained in typical lab-scale photobioreactors. As µ-I curves are the key biological input to an already existing model, it was validated that low density microplate cultivations can be used to make predictions about industrially relevant autotrophic cultivation.

When algae are grown within a wastewater treatment plant, the use of the chemical energy stored in the organic carbon dissolved in the wastewater could also be a useful option. Conventional aerobic sewage treatment expends much energy in breaking down the biomass to CO2. However, various anaerobic treatment methods would result in effluent containing dissolved organic molecules suitable for algae species that have the ability to grow as mixo- or heterotrophs. Chlorella sorokiniana was cultivated in a lab scale photobioreactor under daily light dark cycles and various timing strategies were tested for adding acetate at concentrations that can be obtained in waste streams of 1 – 2 g L-1. The results showed that the fastest growth occurred when adding the acetate at night (cyclic autotrophy/heterotrophy). However adding the acetate during the day (mixotrophy) also improved growth compared to autotrophic controls.

Industrial wastewater was used as cultivation medium of Chlorella sorokiniana. The culture was able to grow at high rates up to a density of 4 g L-1. The deceleration-stat technique was used to create a series of pseudo-steady states to give information about the expected results of continuous cultivation of microalgae in the selected wastewater. At light intensities of 2100 and 200 µmol photon m-2 s-1 the algae grew at a rate of over 5 and 1.67 g L-1day-1, respectively. The corresponding removal rates of nitrogen were 238 and 93 mg L-1day-1 and 40 and 19 mg L-1day-1 for phosphorous. Ammonium removal varied from below 40% to 99%, while phosphate removal was always nearly total. When the biomass was characterized, it was found that fertilizer value N and P content increased with growth rate. For animal feed, the amino acid content was about 40% of biomass. The content of the nutritionally important α-Linoleic fatty acid increased when light intensity and dilution rate were higher. Valuable pigments lutein, carotene and other carotenoids were higher in low-light conditions.

The results from this thesis demonstrate that industrial wastewater can be a suitable replacement for algae cultivation medium. The screening method developed will reduce the cost of identifying the best conditions to test at lab scale. The D-stat method offers a way to identify the best conditions for biomass production and nutrient removal. Various options for heterotrophic and mixotrophic utilization of waste organic carbon in effluents are identified. Further advances in microalgae cultivation and processing will be needed for the production of sustainable products from wastewater in the future.
Enhancement of Protein and Pigment Content in Two Chlorella Species Cultivated on Industrial Process Water

Chlorella pyrenoidosa and Chlorella vulgaris were cultivated in pre-gasified industrial process water with high concentration of ammonia representing effluent from a local biogas plant. The study aimed to investigate the effects of growth media and cultivation duration on the nutritional composition of biomass. Variations in proteins, lipid, fatty acid composition, amino acids, tocopherols, and pigments were studied. Both species grew well in industrial process water. The contents of proteins were affected significantly by the growth media and cultivation duration. Microalga Chlorella pyrenoidosa produced the highest concentrations of protein (65.2% ± 1.30% DW) while Chlorella vulgaris accumulated extremely high concentrations of lutein and chlorophylls (7.14 ± 0.66 mg/g DW and 32.4 ± 1.77 mg/g DW, respectively). Cultivation of Chlorella species in industrial process water is an environmentally friendly, sustainable bioremediation method with added value biomass production and resource valorization, since the resulting biomass also presented a good source of proteins, amino acids, and carotenoids for potential use in aquaculture feed industry.

Er tang fremtidens superfood?

Seaweeds are known for their nutraceutical applications, but also the ability to accumulate e.g. very high iodine concentrations and toxic heavy metals. In this study, cultivated Saccharina latissima (sugar kelp) harvested year-round was analysed for minerals (incl. heavy metals) and vitamins (vit A and E) to evaluate the nutritional value, possible risks and harvest time for optimized value and application. Rope cultivated sugar kelp was sampled both in close proximity to a blue mussel and fish farm (IMTA) and in a reference/control site, both outside Horsens fjord in Denmark, and freeze dried and stored frozen for further analyses. Sugar kelp biomass was sampled (n=3) at 2 m depth in 2013-2014. Surprisingly
high concentrations of K and Ca (up to more than 100 and 150 g/kg DW, respectively) were found, along with other trace
metals: Cr, Fe, Mn, Co, Cu, Na, Zn, and Se. Undesirable elements such as Pb, Hg, and inorganic As were below
legislative threshold values for edible seaweed in France and food supplements in EU, whereas Cd concentrations in
some seasons were above the French limits. However, a 70 kg person would need an intake of 0.77-2.0 kg DW of sugar
kelp to reach the provisional tolerable weekly intake limit set for Cd. The iodine was found in so high levels (up to 5 g/kg)
that this will be the limiting element for intake of sugar kelp. Moreover, the concentrations of total As found from
September to March were above the EU regulatory levels for feed ingredients (40 mg/kg DW. Pb and Cd concentrations
were below threshold values. The vitamin E (alpha-tocopherol) concentrations (6-25 mg/kg DW) were similar to what is
found in broccoli. Generally the year-round variations were due season, and not between the two locations (reference and
IMTA), so harvest time is important for optimized use, and may be conflicting with highest yields of sugar kelp. High
concentrations of iodine and total As may be of concern regarding food and feed regulations, respectively.

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Extraction of alginate from Sargassum muticum: process optimization and study of its functional activities
In the present study, alginate extraction from the brown seaweed Sargassum muticum was studied using single factor
analysis. Response Surface Methodology-Central Composite Rotatary design (RSM-CCRD) was performed to reduce and
optimize extraction temperature, alkali concentration, and consumption of solvent. Different interaction effect of three
extraction factors of temperature (60–100 °C), alkali (1–5 %), and aqueous ethanol (70–100 %) were studied to reduce
residual waste. The result showed that the optimum extraction yield (13.57 %) was obtained with 86 °C temperature, 3 %
alkali, and 93 % ethanol. A second order polynomial equation using multiple regression analysis was developed, and the
predicted extraction yield showed a high coefficient of determination (R 2=0.98) with the experimental alginate yield. The
functionality of extracted alginate and residual supernatant left over after extraction were evaluated for total polyphenols
and its antioxidant capacity. The extracted alginate was further characterized using fluorescence spectrophotometer and
nuclear magnetic resonance spectroscopy. The 1H NMR data revealed that extracted alginate has an M/G ratio of 1.08
and η<1.

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High-EPA Biomass from *Nannochloropsis salina* Cultivated in a Flat-Panel Photo-Bioreactor on a Process Water-Enriched Growth Medium

*Nannochloropsis salina* was grown on a mixture of standard growth media and pre-gasified industrial process water representing effluent from a local biogas plant. The study aimed to investigate the effects of enriched growth media and cultivation time on nutritional composition of *Nannochloropsis salina* biomass, with a focus on eicosapentaenoic acid (EPA). Variations in fatty acid composition, lipids, protein, amino acids, tocopherols and pigments were studied and results compared to algae cultivated on F/2 media as reference. Mixed growth media and process water enhanced the nutritional quality of *Nannochloropsis salina* in laboratory scale when compared to algae cultivated in standard F/2 medium. Data from laboratory scale translated to the large scale using a 4000 L flat panel photo-bioreactor system. The algae growth rate in winter conditions in Denmark was slow, but results revealed that large-scale cultivation of *Nannochloropsis salina* at these conditions could improve the nutritional properties such as EPA, tocopherol, protein and carotenoids compared to laboratory-scale cultivated microalgae. EPA reached 44.2% ± 2.30% of total fatty acids, and α-tocopherol reached 43.1 ± 28 µg/g of biomass dry weight after 21 days of cultivation. Variations in chemical compositions of *Nannochloropsis salina* were studied during the course of cultivation. *Nannochloropsis salina* can be presented as a good candidate for winter time cultivation in Denmark. The resulting biomass is a rich source of EPA and also a good source of protein (amino acids), tocopherols and carotenoids for potential use in aquaculture feed industry.

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Nutrient compensation as management tool– Sugar kelp production in sustainable aquaculture

Integrated multi-trophic aquaculture (IMTA) is theoretically a sustainable production form, which minimizes waste products from e.g. fish farms, by the co-production of bivalves or/and seaweed. For the Danish fish farmers the extractive organisms could be the solution for increasing fish production, but do the principles of IMTA fully mitigate the nutrient impact from open net-pen fish production at realistic production scales?

In this project, commercial scale cultivation of sugar kelp (Saccharina latissima) was investigated with regard to operation, yield, biofilter capacity and mapping the biomass composition for one year incl. protein content, amino acid profiles, lipids and fatty acid composition, minerals and vitamins. Results were obtained from an IMTA site and compared to a reference site with no impact from the fish (175 t year−1) and mussel farm, both located just outside Horsens Fjord, Denmark. The nitrogen content in sugar kelp varied between 0.5-3.7% of dw with the highest concentration in September 2013 with an estimated maximum yield of 5.1-7.1 tons ww ha−1 year−1. Potentially, a cultivation area of 204-340 ha would be needed to achieve 100% N recovery, based on the tonnage of the specific fish farm. The harvest contained protein (10%), lipids (3%) and vitamin A (34 mg/kg per dw), however with large seasonal variations. Sugar kelp increased the biodiversity by...
functioning as hanging reefs, but did not significantly affect the sediment by shading (5% in a scenario of 5 kg/meter dropper rope). During the project a number of improvements of the existing techniques for producing seaweed on suspended line systems were developed, however, further optimization of techniques for deployment, production as well as harvest is needed. This would also allow sugar kelp production as a viable and robust mitigation tool for nitrogen removal and hopefully allow for future expansion of sustainable marine fish production in Denmark.

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Recent developments on biofuels production from microalgae and macroalgae

Biofuels from algae are considered as promising alternatives of conventional fossil fuels, as they can eliminate most of the environmental problems. The present study focuses on all the possible avenues of biofuels production through biochemical and thermochemical conversion methods in one place, bringing together both microalgae and macroalgae on the same platform. It provides a brief overview on the mechanism of different biofuel production from algae. Factors affecting the biofuel process and the associated challenges have been highlighted along with analysis of techno-economic study available in literature. Undoubtedly, biodiesel is the center of attraction among other biofuels. However, their routes and process need to be optimized in order to bring the minimum fuel selling price (MFSP) of biodiesel competitive. Technological challenges have not been overcome to make biofuel production process energetically and commercially viable. Macroalgae are low in lipid content. Therefore, the use of macroalgae is restricted for gaseous fuels or fermentative methods of liquid biofuels production. Anaerobic digestion of algal biomass is easy and seems promising as the process is simple in terms of engineering and infrastructure requirement. Hydrogen production by microalgae through biophotolysis seems interesting as it directly converts the solar energy into hydrogen. However, the process has not been scaled-up till today. Hydrothermal liquefaction (HTL) is more promising due to handling of wet biomass at moderate temperature and pressure and conversion of whole biomass into high quality oil. However, HTL process is energy intensive.


Seasonal variations of antioxidants in the brown seaweed *Saccharina latissima*

Mainly the brown seaweeds are known for their high antioxidative capacity within the specific compounds such as phlorotannins, polyphenols, flavonoids, pigments, and these natural antioxidants are of high industrial interest. Previous studies have shown large seasonal variations in biomass composition. The aim of this study was to see if there was a seasonal variation in the antioxidant content of sugar kelp (*Saccharina latissima*), compare two cultivation sites, REF and IMTA, and test different solvents applied for extractions, methanol or ethyl acetate. Rope cultivated sugar kelp were sampled both in close proximity to a blue mussel and fish farm (IMTA) and at a reference/control site (REF), both outside Horsens fjord in Denmark. Sugar kelp biomass was measured (n=3) at 2 m depth in 2013-2014, and freeze dried and stored frozen for further analyses. In relation to the extraction, two solvents with different polarities were applied. Methanol was generally a better solvent for extracting the more polar compounds i.e. phenolics, whereas ethyl acetate tended more efficient for flavonoid extraction. There was no significant variation in the TAC between the two cultivation sites, ranging between 1,531-5,135 μg GA/g DW, and with no clear pattern of seasonal variation. Within the phenolic content no significant difference was seen (258-3,594 μg GA/g DW), and for IMTA the flavonoid concentration for September 2013 (4,830±1,048 μg rutin/g DW) was significantly higher than the other months. The biological variability had a high impact revealed by large standard deviation. The pigment specimens did not change during the year, however the concentration did, and with fucoxanthin as the most interesting. No clear correlation was found between pigments and the antioxidants.

This study showed high concentration of antioxidant in sugar kelp and in 100 times higher range than e.g. microalgae. However, the large variations should be taken into account when aiming for industrial use.
The inner Danish waters as suitable seaweed cultivation area- evaluation of abiotic factors
Increased production of macroalgae may contribute to solving e.g. the demand for food globally. Palmaria palmata and Saccharina latissima are at present demanded and cultivated in European waters, and can potentially be cultivated at even larger scale. The present study investigated suitable cultivation areas in Danish waters for these two algal species in regard to a variation in the abiotic conditions: light, temperature, and the unusual salinity gradient through the inner Danish waters towards the Baltic Sea. Published tolerance levels of the abiotic conditions of the species were reviewed and compared to surveillance data on presence of the species and to empiric abiotic data at five sites in Denmark. Furthermore, in situ experiments were conducted at the locations by deployed vertical ropes with inserted adults of P. palmata and S. latissima at 1-6 m depth. The analysis of the abiotic conditions showed, that light conditions are sufficient to meet the light saturation level of both algae, but large seasonal and a site specific variations in light attenuation determine optimal cultivation depth. Water temperatures were found to exceed the tolerance level for P. palmata in July, August, and September and for S. latissima in August at some sites. A large geographical variation in salinity was seen between sites, with salinities below the tolerance level of P. palmata at most sites. The results the in situ experiments showed increased biomass over a seven months cultivation period for both species at salinities down to 21±3 PSU, and at the low salinity site (17±5 PSU) P. palmata turned green while continuing growing. This most likely due to stress such as low salinity and light. Cultivation of P. palmata near Fredericia provided the highest specific growth rate of 0.038 d-1 which was significant from the other sites. These findings were further discussed and the inner Danish waters evaluated as suitable location for cultivation of the assessed species.

Variation in growth and quality of Saccharina latissima cultivated in the Faroe Islands
Macroalgae cultivation is a developing industry in the western part of the world, and in the Faroe Islands experimental cultivation including Alaria esculenta, Laminaria hyperborea and Saccharina latissima, has been carried out since 2005. The cultivation experiments with A. esculenta and S. latissima have shown promising results with regard to growth and yield, but the quality and composition of the cultivated biomass has not been investigated. Protein level and amino acid composition are essential factors when estimating the quality of the produced biomass for food and/or feed, but how does e.g. seasonality, exposure and nutrient levels affect these factors. Current work investigated growth and yield in cultivated S. latissima in a sound in the Faroe Islands, and studied the variation in total Kjeldal nitrogen, nitrate and protein content and changes in amino acid composition with regard to season (spring and summer), and exposure (current exposed, wave exposed and sheltered). To enable comparison we also investigated the variation in total Kjeldal nitrogen, nitrate and protein content and changes in amino acid composition in wild S. latissima populations. In the cultivated biomass there was a significantly lower yield at the current exposed site (5.2 ± 0.4 kg m-1) compared to the sheltered (9.9 ± 1.3 kg m-1) and the wave exposed (8.0 ± 1.5 kg m-1). The growth rate (SGR) did not differ with regard to exposure, however the weight of the individuals at the current exposed site was significantly higher compared to the individuals at the sheltered and wave exposed sites throughout the cultivation period. In both the cultivated biomass and the natural populations a significant seasonal differences was observed in total Kjeldal nitrogen, nitrate and protein levels and amino acid composition. A significant difference related to exposure degree was observed in total Kjeldal nitrogen and nitrogen, but this was not observed for protein and amino acid composition.
Bioremediation Potential of Sugarkelp, Saccharina Latissima, Cultivated in a Commercial Off-Shore Integrated Multi-Trophic Aquaculture

General information
State: Published
Organisations: Department of Environmental Engineering, Residual Resource Engineering, National Food Institute, Division of Industrial Food Research
Authors: Silva Marinho, G. (Intern), Holdt, S. L. (Intern), Angelidaki, I. (Intern)
Publication date: 2015
Main Research Area: Technical/natural sciences
Electronic versions:
ISAP2014_Sugarkelp_as_biofilter_GSMarinho_et_al_final_.pdf

Relations
Activities:
5th Congress of the International Society for Applied Phycology
Publication: Research - peer-review › Conference abstract for conference – Annual report year: 2015

Commercial cultivation and bioremediation potential of sugar kelp, Saccharina latissima, in Danish waters
Several seaweed species have been successfully tested for their biofilter potential for integrated multi-trophic aquaculture (IMTA). In this study, Saccharina latissima bioremediation potential was assessed over 12 months with respect to the yield, phosphorous (P), nitrogen (N) content and N removal. The experiment took place at two commercial cultivation areas; in close proximity to a blue mussel and fish farm (IMTA) and at a reference site, both situated outside Horsens fjord in Denmark. The maximum biomass yield over the first growing season was achieved in August (1.08±0.09 and 1.51±0.13 kg FW m⁻¹) and September (0.92±0.18 and 1.49±0.16 kg FW m⁻¹). Yield was significantly higher at the IMTA compared to the reference site in August (P<0.05). A second growing season did not improve biofiltration efficiency. The highest N and P removal was achieved in August and September. Again the IMTA location showed better N and P removal compared with the reference site in August; 5.02-7.02 g N and 0.86-1.23 g P m⁻¹ of cultivation line (P<0.05). S. latissima shows potential for assimilation and removal of nutrients, particularly nitrogen. Seasonal variations of biofilter efficiency, conditions and potential applications should be taken into account when evaluating the best suited harvest time. For Horsens fjord, our results showed that the harvest time should take place in August-September in order to achieve maximum biofiltration efficiency (including N and P in epiphytes). However, for human consumption, it is better to harvest in May where the seaweed is free of epiphytes.

General information
State: Published
Organisations: Department of Environmental Engineering, Residual Resource Engineering, National Food Institute, Division of Industrial Food Research, DHI Denmark
Authors: Silva Marinho, G. (Intern), Holdt, S. L. (Intern), Birkeland, M. J. (Ekstern), Angelidaki, I. (Intern)
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Main Research Area: Technical/natural sciences

Publication information
Journal: Journal of Applied Phycology
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Issue number: 5
ISSN (Print): 0921-8971
Effect of nitrogen source and acclimatization on specific growth rates of microalgae determined by a high-throughput in vivo microplate autofluorescence method

Specific growth rates (SGR) of freshwater alga species (Chlorella vulgaris, Auxenochlorella protothecoides and Chlorella sorokiniana) and the marine species Nannochloropsis oculata on various nitrogen sources (ammonium carbonate, ammonium chloride, sodium nitrate, and urea) could be determined by in vivo chlorophyll-a autofluorescence. These preferences could be determined before large pH changes occurred in the media, with no significant difference (P>0.05) between buffered and non-buffered media. In all algal species, acclimatization was observed with no significant difference (P>0.05) between SGRs of the second and third cultivations. ANOVA of SGRs in the acclimatized second and third cultivations revealed preferences for nitrogen sources among most of the algae: C. vulgaris preferred sodium nitrate over other nitrogen sources, A. protothecoides adapted to urea after no growth in the first cultivation, and the SGRs of N. oculata showed an aversion for sodium nitrate over other nitrogen sources (P<0.05).

General information
State: Published
Organisations: Department of Environmental Engineering, Residual Resource Engineering, National Food Institute, Division of Industrial Food Research
Authors: Podevin, M. (Intern), De Francisci, D. (Intern), Holdt, S. L. (Intern), Angelidaki, I. (Intern)
Evaluation of the Danish cultivated sugarkelp as possible future source of ingredients such as minerals and pigments

General information
State: Published
Organisations: National Food Institute, Research Group for Bioactives – Analysis and Application, Department of Environmental Engineering, Residual Resource Engineering, Research Group for Nano-Bio Science
Authors: Holdt, S. L. (Intern), Silva Marinho, G. (Intern), Sloth, J. J. (Intern), Safafar, H. (Intern), Jakobsen, J. (Intern), Angelidaki, I. (Intern)
Lipids and Composition of Fatty Acids of Saccharina latissima Cultivated Year-round in Integrated Multi-trophic Aquaculture

This study is evaluating the seasonal lipid and fatty acid composition of the brown seaweed Saccharina latissima. Biomass was sampled throughout the year (bi-monthly) at the commercial cultivation site near a fish farm in an integrated multi-trophic aquaculture (IMTA) and at a reference site in Denmark (2013-2014). Generally, there was no difference in the biomass composition between sites; however, significant seasonal changes were found. The lipid concentration varied from 0.62%-0.88% dry weight (DW) in July to 3.33%-3.35% DW in November (p < 0.05) in both sites. The fatty acid composition in January was significantly different from all the other sampling months. The dissimilarities were mainly explained by changes in the relative abundance of 20:5n-3 (13.12%-33.35%), 14:0 (11.07%-29.37%) and 18:1n-9 (10.15%-16.94%). Polyunsaturated fatty acids (PUFA's) made up more than half of the fatty acids with a maximum in July (52.3%-54.0% fatty acid methyl esters; FAME). This including the most appreciated health beneficial PUFA's, eicosapentaenoic (EPA; 20:5n-3) and docosahexaenoic acid (DHA; 22:6n-3), but also arachidonic (ARA) and stearidonic acid (SDA), which are not found in land vegetables such as cabbage and lettuce. Compared to fat (salmon) and lean fish (cod) this seaweed species contains higher proportions of ARA and SDA, but lower EPA (only cod) and DHA. Conclusively, the season of harvest is important for the choice of lipid quantity and quality, but the marine vegetables provide better sources of EPA, DHA and long-chain (LC)-PUFA's in general compared to traditional vegetables.
Microalgal bioremediation of nutrients in wastewater and production of food/feed ingredients

General information
State: Published
Organisations: National Food Institute, Research Group for Bioactives – Analysis and Application, Ecolipids A/S
Authors: Safafar, H. (Intern), Møller, P. (Ekstern), Holdt, S. L. (Intern), Jacobsen, C. (Intern)
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Publisher: Technical University of Denmark (DTU)
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Seasonal Amino Acid Profile and Nutritional Value of Saccharina Latissima in a Commercial IMTA System

General information
State: Published
Organisations: National Food Institute, Division of Industrial Food Research, Department of Environmental Engineering, Residual Resource Engineering
Authors: Holdt, S. L. (Intern), Silva Marinho, G. (Intern), Angelidaki, I. (Intern)
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Publication date: 2015
Main Research Area: Technical/natural sciences

Relations
Activities:
5th Congress of the International Society for Applied Phycology
4th Nordic Seaweed Conference
Publication: Research › Conference abstract for conference – Annual report year: 2015

Seasonal variations in the amino acid profile and protein nutritional value of Saccharina latissima cultivated in a commercial IMTA system
Seaweeds have potential for the provision of biomass for food and feed supplements. The demand is increasing especially for proteins as ingredients; however, the amino acid profile is essential for evaluation of the nutritional value of proteins. The year-round protein concentration and amino acid profiles of Saccharina latissima were determined, and the harvest time and nutritional potential were evaluated. Bi-monthly samples were analyzed from S. latissima (including epiphytes, when present) cultivated commercially at an integrated multi-trophic aquaculture (IMTA) site and a reference site in Denmark in 2013–2014. Overall, there was no significant difference for the tested parameters between the two sampling sites; however, seasonal variations were found. The protein concentration varied markedly reaching a maximum of 10.8 % dry weight (DW) in November and a minimum of 1.3 % DW in May 2013. Aspartic and glutamic acids dominated the amino acid profile, accounting for up to 49 % of the total. Greatest seasonal differences in amino acid composition occurred in July, with leucine contributing most (22.7–26.7 %) of the observed differences. A maximal essential amino acid (EAA) score of 68.9 % (based on WHO/FAO/UNU requirements) was achieved in November 2013. The presence of epiphytes in July to November changed neither the amino acid content nor the EAA score. S. latissima is comparable with wheat as a protein ingredient for fish feed and appears to be a suitable protein/amino acid source for human consumption. This study proposes that there may be a mismatch between harvest time and nutritional value. The preferable harvest time for S. latissima is November, due to high protein content and EAA score. However, higher yield and cleaner biomass for human consumption would be found in May.

General information

State: Published
Organisations: Department of Environmental Engineering, Residual Resource Engineering, National Food Institute, Division of Industrial Food Research
Authors: Silva Marinho, G. (Intern), Holdt, S. L. (Intern), Angelidaki, I. (Intern)
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BFI (2017): BFI-level 1
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BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 2.46
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 2.32
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): CiteScore 2.88
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): CiteScore 2.78
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): CiteScore 2.68
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): CiteScore 2.29
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 1
BFI (2008): BFI-level 1
Seaweed potentials – evaluation of year-round biomass composition of commercial cultivated sugarkelp - results from project KOMBI

In this study, the year-round protein, amino acid, fatty acid, pigments, mineral and vitamin content and profiles were considered to evaluate the nutritional value and harvest time of the Saccharina latissima biomass for optimized value and application. Sugarkelp was cultivated both in close proximity to a blue mussel and fish farm (IMTA) and in a reference site, both outside Horsens fjord in Denmark. Sugarkelp biomass was measured by harvesting sporophytes (deployed in February 2013) from 1 m rope droppers (n=3) at 2 m depth in 2013-2014. Biomass was weighed, followed by freeze drying, homogenizing and chemical characterization by various methods for the specific analyses of biomass composition. Protein content varied throughout the experimental period with the highest values recorded in November (10.8%) and the lowest values recorded in May 2013 (1.3 %). The lipid concentration varied from 0.62-0.88% DW in July to 3.33-3.35% DW in November (P<0.05). Polyunsaturated fatty acids (PUFA’s) made up more than half of the fatty acids with a maximum in July (52.3-54.0% FAME), including the most appreciated health beneficial EPA and DHA. Mineral content are discussed in relation to legislations, and a few trace metals such as Cd, Pb, Iodine may be problematic in some seasons. The pigment profile did not change during the year, however the concentration did, and with fucoxanthin as the most interesting. Generally the year-round variations were due season, and no difference between the two locations (reference and IMTA).

General information
State: Published
Organisations: National Food Institute, Research Group for Bioactives – Analysis and Application, Department of Environmental Engineering, Residual Resource Engineering
Authors: Holdt, S. L. (Intern), Silva Marinho, G. (Intern), Angelidaki, I. (Intern)
Number of pages: 1
Publication date: 2015
Event: Abstract from 5th Nordic Seaweed Conference, Grenaa, Denmark.
Main Research Area: Technical/natural sciences
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The Commercial IMTA and Future Seaweed Biofilter Potential in Denmark

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State: Published
Organisations: National Food Institute, Division of Industrial Food Research
Authors: Holdt, S. L. (Intern)
Number of pages: 16
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Main Research Area: Technical/natural sciences
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The_Commercial_IMTA_and_future_seaweed_biofilter_potential_SLHoldt_final.pdf

Relations
Activities:
The Commercial IMTA and future seaweed biofilter potential in Denmark
Publication: Research › Sound/Visual production (digital) – Annual report year: 2015
The extraction of nutrients from a danish fish farm (Oncorhynchus mykiss) by mussels (Mytilus edulis) and sugar kelp (Laminaria saccharina): integrated multi-trophic aquaculture

General information
State: Published
Organisations: National Food Institute, Research Group for Bioactives – Analysis and Application, Orbicon, Hjarnø Aquaculture A/S, National Food Institute, Danish Aquaculture Association
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Main Research Area: Technical/natural sciences

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Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): SJR 0.433 SNIP 0.644 CiteScore 1.01
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.5 SNIP 0.75 CiteScore 1.02
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 0.425 SNIP 0.488 CiteScore 0.8
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 0.564 SNIP 0.693 CiteScore 1.03
ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 0.446 SNIP 0.647 CiteScore 1
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 0.548 SNIP 0.632 CiteScore 1.01
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 0.547 SNIP 0.628
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 0.477 SNIP 0.549
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 0.371 SNIP 0.551
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 0.492 SNIP 0.674
Scopus rating (2006): SJR 0.492 SNIP 0.615
Scopus rating (2005): SJR 0.397 SNIP 0.624
Scopus rating (2004): SJR 0.474 SNIP 0.757
A novel closed system bubble column photobioreactor for detailed characterisation of micro- and macroalgal growth

Growth of the marine microalga Tetraselmis striata Butcher and the macroalga Chondrus crispus Stackhouse was investigated in batch cultures in a closed system bubble column photobioreactor. A laboratory cultivation system was constructed that allowed online monitoring of pH and dissolved oxygen tension and was used for characterization of photoautotrophic growth. Carbon dioxide addition regulated pH and was used to optimise irradiance. Oxygen was removed from the system by addition of hydrogen over a palladium catalyst to quantify oxygen production. In addition, the bubble column photobioreactor was suited for cultivation of algae due to fast gas-to-liquid mass transfer (kLa) and fast mixing provided by split and dual sparging. Specific growth rates (SGRs) were measured using both offline and online measurements. The latter was possible, because rectilinear correlation was observed between carbon dioxide addition and optical density, which shows that carbon dioxide addition may be used as an indirect measurement of microalgal biomass (x). The slope of the rectilinear fit of ln(dx/dt) as a function of the time (t) then revealed the SGR. These determinations revealed detailed information about changes in growth with up to three different SGRs in the different batch cultures of both micro- and macroalgae. The maximum SGRs found by online determination were 0.13 h-1 for T. striata and 0.12 day-1 for C. crispus. We have developed and described a system and presented some data handling tools that provide new information about growth kinetics of algae. © 2013 Springer Science+Business Media Dordrecht.
Cost-effective IMTA: a comparison of the production efficiencies of mussels and seaweed

This paper compares the biofilter capacity and cost-effectiveness of blue mussels (Mytilus edulis) and seaweed for use in integrated multi-trophic aquaculture (IMTA) based on experiences in Ireland and Denmark. This comparison shows that weight for weight, mussels are a better biofilter than seaweed with regard to the amount of nitrogen assimilated. Furthermore, in optimized systems, areal requirement for mussels is similar to the cultivation of the same tonnage (1,000 t) of seaweed (approximately 8 ha). The cost-effectiveness of a mussel biofilter is €11–30 kg⁻¹ nitrogen (N) removed based on various examples compared to production costs of €209–672 removed and €1,013 kg⁻¹ N removed, respectively, for Laminaria digitata and Alaria esculenta from extrapolated laboratory and field trials. However, commercial seaweed (Saccharina latissima) producers claim that production costs are less than €10–38 kg⁻¹ N removed. These up-scaled and commercial figures make the seaweed cost competitive to mussels for removal of nitrogen. Disadvantages such as predators (e.g. eider ducks) and biofouling should also be taken into account before choice of biofilter is made. These drawbacks can reduce overall biofilter capacity and biomass value as a consequence of biomass spoilage or loss. However, disadvantages may be mitigated by seasonal choice of cultivation and harvest times. Cultivation technologies and harvesting methods may be improved together with breeding to improve the cost-efficiency of the biofilter, especially in the newer European seaweed cultivation. Furthermore, upscaling of IMTA to commercial proportions, other than the Danish example, would allow more real data on production costs and revenues.

General information
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Organisations: National Food Institute, Division of Industrial Food Research, The Ryan Institute
Authors: Holdt, S. L. (Intern), Edwards, M. D. (Ekstern)
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Main Research Area: Technical/natural sciences

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BFI (2017): BFI-level 1
Web of Science (2017): Indexed Yes
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Scopus rating (2016): CiteScore 2.46
Web of Science (2016): Indexed yes
Effective harvesting of the microalgae *Chlorella protothecoides* via bioflocculation with cationic starch.

In the present work, the flocculation efficiency of cationic starch (*Greenfloc* 120) was tested on the fresh water microalga *Chlorella protothecoides* under different conditions (pH and flocculant concentrations). Different concentrations of *Greenfloc* 120 (0, 2.5, 5, 10, 20, 40mgL\(^{-1}\)) were screened against different algal densities (0.44, 0.56 and 0.77gL\(^{-1}\)). Once the optimal flocculation concentration had been established (40mgL\(^{-1}\)) for all different biomasses densities) a more detailed analysis was performed in order to investigate if different pH (4.0, 7.7, and 10.0) could increase the flocculation efficiency of cationic starch. Highest flocculation efficiency without addition of *Greenfloc* 120 was obtained at pH 10, while in the presence of flocculant, the efficiency increased for all the tested pH values, with a maximum of 98% for pH 7.7 and 10. Cationic starch confirmed to be as an easy to use, efficient and cost-effective flocculant for harvesting of microalgae.

**General information**

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**Publication information**

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Scopus rating (2016): CiteScore 5.94 SJR 2.191 SNIP 1.91
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 2.255 SNIP 1.908 CiteScore 5.47
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 2.41 SNIP 2.104 CiteScore 5.3
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 2.412 SNIP 2.503 CiteScore 5.97
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 2.389 SNIP 2.465 CiteScore 5.25
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 2.314 SNIP 2.508 CiteScore 5.56
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 2.086 SNIP 2.355
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 1.912 SNIP 2.231
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 1.734 SNIP 2.732
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 1.529 SNIP 2.423
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 1.315 SNIP 1.98
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 1.269 SNIP 2.006
Web of Science (2005): Indexed yes
Scopus rating (2004): SJR 1.197 SNIP 1.659
Web of Science (2004): Indexed yes
Scopus rating (2003): SJR 0.948 SNIP 1.639
Web of Science (2003): Indexed yes
Scopus rating (2002): SJR 0.882 SNIP 1.3
Web of Science (2002): Indexed yes
Scopus rating (2001): SJR 0.541 SNIP 1.208
Scopus rating (2000): SJR 0.464 SNIP 1.049
Scopus rating (1999): SJR 0.669 SNIP 1.061
Original language: English
Chlorella protothecoides, Flocculation, Cationic starch
DOIs:
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Source-ID: 268332253
Publication: Research - peer-review › Journal article – Annual report year: 2014
Integrated multi-trophic aquaculture (combined production of fish, mussels and seaweed)

The Danish marine aquaculture has, despite the huge potential, only been slowly increasing the last 25 years because of the imposed limits to the nitrogen (N) released to the environment. Mussels, seaweed and other organisms have been successfully tested as biofilters in integrated multi-trophic aquaculture (IMTA) worldwide, where nutrients emissions (especially N) from e.g. fish production are assimilated and removed by valuable biomasses (crops; Fig.1). This IMTA production unit, and even spatial decoupling of the biofilter organisms from the fish, have been recognized by the Danish national authorities in off-shore fish farming. The bioremediation potential and yield of the “new” crop, seaweed (sugarkelp, Saccharina latissima) was monitored in a commercial off-shore IMTA system year round at Hjarnø Havbrug fish farm near Horsens. Furthermore, the year-round protein, amino acid, fatty acid, mineral and vitamin content and profiles were monitored to evaluate the nutritional value and harvest time of the seaweed biomass. Sugarkelp showed to be efficient for bioremediation of nitrogen, with environmental and potentially economic benefits (e.g. waste water management and for production of valuable biomass). The seaweed protein content varied throughout the experimental period with the highest values recorded in November (14-20% of dry weight) and the lowest values recorded in May-July (2.8-6.7%). The lowest lipid content was observed in July, while the highest values were observed in November (approx. 4% of dw), with EPA (20:5(n-3)) and DHA (22:6(n-3)) accounting for 11.3-14.4% and 2.5-4.6% of total fatty acids, respectively. This “new” Danish aquatic crop has potential applications. The harvest time should be settled around May for human consumption and September in order to achieve maximum biofiltration efficiency with harvested biomass for feed utilization. This considering both biology/life cycle, biofouling and yield, which may compromise with seasons with higher nutritional value of the produced biomass.

General information
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Relations
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Publication: Research - peer-review › Conference abstract in proceedings – Annual report year: 2014

Microplate-based method for high-throughput screening of microalgae growth potential

Microalgae cultivation conditions in microplates will differ from large-scale photobioreactors in crucial parameters such as light profile, mixing and gas transfer. Hence volumetric productivity (Pv) measurements made in microplates cannot be directly scaled up. Here we demonstrate that it is possible to use microplates to measure characteristic exponential growth rates and determine the specific growth rate light intensity dependency (μ-I curve), which is useful as the key input for several models that predict Pv. Nannochloropsis salina and Chlorella sorokiniana specific growth rates were measured by repeated batch culture in microplates supplied with continuous light at different intensities. Exponential growth unlimited by gas transfer or self-shading was observable for a period of several days using fluorescence, which is an order of magnitude more sensitive than optical density. The microplate datasets were comparable to similar datasets obtained in photobioreactors and were used an input for the Huesemann model to accurately predict Pv.

General information
State: Published
Organisations: Department of Environmental Engineering, Residual Resource Engineering, Urban Water Engineering
Authors: Van Wagenen, J. (Intern), Holdt, S. L. (Intern), De Francisci, D. (Intern), Valverde Perez, B. (Intern), Plósz, B. G. (Intern), Angelidaki, I. (Intern)
Number of pages: 7
Pages: 566-572
Publication date: 2014
Main Research Area: Technical/natural sciences

Publication information
Journal: Bioresource Technology
Volume: 169
Optimization of extraction process of crude alginate from Sargassum muticum by response surface methodology

General information
State: Published
Organisations: National Food Institute, Division of Industrial Food Research, Department of Environmental Engineering, Residual Resource Engineering, Indian Institute of Technology
Number of pages: 1
Publication date: 2014
Main Research Area: Technical/natural sciences
Electronic versions:
ISAP_Poster_alginate_Anupriya_final.pdf

A novel closed system bubble column photobioreactor for detailed characterisation of micro and macroalgal growth

Growth of the marine microalgae Tetraselmis striata Butcher and macroalgae Chondrus crispus Stackhouse was investigated in batch cultures in a closed system bubble column photobioreactor. A laboratory cultivation system was constructed that allowed on-line monitoring of temperature, pH and dissolved oxygen tension and was intended for characterization of photoautotrophic growth. Regulation of temperature was done by cooling and carbon dioxide additions regulated pH. The carbon dioxide addition rate was used to optimize irradiance and thereby optimizing growth conditions. Photosynthetically produced oxygen was catalytically removed from the closed system by addition of hydrogen over a palladium catalyst to avoid photorespiration and to quantify oxygen production. In addition, the bubble column photobioreactor was well suited for cultivation of algae due to fast gas to liquid mass transfer (kLa) and fast mixing provided by split and dual sparging. Specific growth rates (SGRs) were measured using both off-line and on-line measurements. The latter was possible, because linear correlation was observed between carbon dioxide addition and optical density, which proves that carbon dioxide addition may be used as an indirect measurement of biomass (x). The slope of the rectilinear fit of ln (dx/dt) as function of the time (t) then revealed the SGR. This allowed on-line determination of the SGR, and these determinations revealed detailed information about changes in growth with up to three different SGRs in the different batch cultures of both micro and macroalgae. The algal SGR is normally considered to be constant. The maximum SGRs found by on-line determination were 0.13 hr⁻¹ for T. striata and 0.12 d⁻¹ for C. crispus. During batch cultivation growth stoichiometry was determined and photosynthetic quotients and carbon mass balances were used to validate the system. We have developed a system and presented some data handling tools that provides new information about the growth kinetic of algae.

General information
State: Published
Organisations: Department of Environmental Engineering, Residual Resource Engineering, Chr. Hansen A/S, Sdr. Boulevard 296B
Authors: Holdt, S. L. (Intern), Christensen, L. (Ekstern), Iversen, J. J. (Ekstern)
Number of pages: 1
Publication date: 2013
Main Research Area: Technical/natural sciences
Electronic versions:
prod11387273258014.PBR_characterization_of_algal_growth_SLHoldt.pdf
Source: dtu
Source-ID: u::10044
Publication: Research - peer-review › Conference abstract for conference – Annual report year: 2013

Cost-effective IMTA: a comparison of the production efficiencies of mussels and seaweed

This paper compares the biofilter capacity and cost-effectiveness of blue mussels (Mytilus edulis) and seaweed for use in integrated multi-trophic aquaculture (IMTA) based on experiences in Ireland and Denmark. This comparison shows that weight for weight, mussels are a better biofilter than seaweed with regard to the amount of nitrogen assimilated.
Furthermore, in optimised systems, areal requirement for mussels is similar to the cultivation of the same tonnage (1,000 t) of seaweed (approx. 8 ha). The cost-effectiveness of a mussel biofilter is €11.4-19.2 kg-1 N removed based on modeled results compared to production cost of €209-672 kg-1 N removed and €1,013 kg-1 N removed for respectively Laminaria digitata and Alaria esculenta from extrapolated laboratory and field trials. However, a commercial seaweed (Saccharina latissima) producer claims that production costs are less than €10 kg-1 N removed. This up-scaled and commercial figure makes the seaweed cost competitive to mussels for removal of nitrogen.

Disadvantages such as predators (e.g. eider ducks) and bio-fouling should also be taken into account before choice of biofilter is made. These drawbacks can reduce overall biofilter capacity and biomass value as a consequence of biomass spoilage or loss. However, disadvantages may be mitigated by seasonal choice of cultivation and harvest times. Cultivation technologies and harvesting methods may be improved together with breeding to improve the cost-efficiency of the biofilter, especially in the “newer” European seaweed cultivation. Furthermore, upscaling of IMTA to commercial proportions, other than the Danish example, would allow more real data on production costs and revenues.

General information
State: Published
Organisations: Department of Environmental Engineering, Residual Resource Engineering, The Ryan Institute
Authors: Holdt, S. L. (Intern), Edwards, M. D. (Ekstern)
Number of pages: 1
Publication date: 2013
Event: Abstract from Danish Macro Algae Conference 2013, Grenaa, Denmark.
Main Research Area: Technical/natural sciences
Electronic versions:
prod11387272986706.Cost_effective_IMTA_Holdt_and_Edwards.pdf
Source: dtu
Source-ID: u::10043
Publication: Research - peer-review › Conference abstract for conference – Annual report year: 2013

Development and evaluation of a fast screening method of microalgal performance using microplates

General information
State: Published
Organisations: Department of Environmental Engineering, Residual Resource Engineering, Technical University of Denmark
Authors: Holdt, S. L. (Intern), De Francisci, D. (Intern), Angelidaki, I. (Intern), Borch, M. M. (Ekstern)
Number of pages: 1
Publication date: 2013
Event: Poster session presented at International Conference on Algal Biorefinery, Kharagpur, India.
Main Research Area: Technical/natural sciences
Electronic versions:
High through put screening method-final.pdf
Source: dtu
Source-ID: u::6586
Publication: Research - peer-review › Poster – Annual report year: 2013

Development of an algal wastewater treatment concept, based on the selection of microalgal strains with optimal bioextraction characteristics

General information
State: Published
Organisations: Department of Environmental Engineering, Residual Resource Engineering, Environmental Chemistry, Urban Water Engineering, Cluster Biofuels Denmark
Number of pages: 1
Publication date: 2013
Event: Poster session presented at International Conference on Algal Biorefinery, Kharagpur, India.
Main Research Area: Technical/natural sciences
Electronic versions:
e4water 4-final.pdf
Source: dtu
Source-ID: u::6589
Publication: Research - peer-review › Poster – Annual report year: 2013
Growth of Saccharina and Palmaria compared to chemical and physical parameters in the inner Danish waters

Algae as feedstock for high value-added products such as nutraceuticals and low value product such as energy are getting more attention in Denmark. Few macroalgal producers have initiated off shore cultivation of macroalgae, even though the high demand on cultivation ropes and algal biomass. Algal biomass (and the seeded cultivation ropes) is the bottleneck in algal research as well as business in Denmark. Furthermore, cultivation experiments are needed to investigate the suitability of the inner Danish water (with e.g. decreasing salinity, and different nutrient regimes) for macroalgal cultivation.

Macroalgae will be cultivated on ropes deployed at 6 locations in the sea more specifically Limfjorden in the North to further South in Horsens, Fredericia, Fåborg, Agersø and Bissersup in the Southern part of Denmark. Among other things, salinity and nutrient availability are important variables for the fitness and growth of macroalgae. The macroalgae will be deployed at 2 depths; 3 m and 6 m to see a possible effect of halocline (salinity stratification). Growth data of weight, length and biomass composition (especially N, P, TS, VS) will be analyzed in different seasons. A modeling in the Geographical Information System ArcGIS on the obtained field data compared to the chemical and physical parameters (e.g. salinity (halocline), nutrient availability, currents, and cultivation areas for organic macroalgae). The macroalgal growth, biomass composition, the ArcGIS, and the field samples on the variables will give a map of suitable areas for S. lattissima and P. palmata cultivation in the inner Danish waters. The hypothesis is that the macroalgae perform better at higher salinities (further North and/or below the halocline) and in nutrient rich areas where light is not limited.

General information
State: Published
Organisations: Department of Environmental Engineering, Residual Resource Engineering, Roskilde Universitet
Authors: Holdt, S. L. (Intern), Grandorf, U. S. (Ekstern), Angelidaki, I. (Intern), Pedersen, M. F. (Ekstern)
Number of pages: 1
Publication date: 2013
Event: Abstract from International Conference on Algal Biorefinery, Kharagpur, India.
Main Research Area: Technical/natural sciences
Electronic versions:
Source: dtu
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Publication: Research - peer-review › Conference abstract for conference – Annual report year: 2013

High effective harvesting of microalgae Chlorella prothotocoides via flocculation with cationic starch

General information
State: Published
Organisations: Department of Environmental Engineering, Residual Resource Engineering
Authors: Letelier Gordo, C. O. (Intern), Karakashev, D. B. (Intern), Holdt, S. L. (Intern), Angelidaki, I. (Intern)
Number of pages: 1
Publication date: 2013
Event: Poster session presented at International Conference on Algal Biorefinery, Kharagpur, India.
Main Research Area: Technical/natural sciences
Electronic versions:
1.pdf
Publication: Research - peer-review › Poster – Annual report year: 2013

Increasing the precision of microplate measurements of algal growth rate

General information
State: Published
Organisations: Department of Environmental Engineering, Residual Resource Engineering, Technical University of Denmark
Authors: Van Wagenen, J. (Intern), Moure Abelenda, A. (Ekstern), De Francisci, D. (Intern), Holdt, S. L. (Intern), Angelidaki, I. (Intern)
Number of pages: 1
Publication date: 2013
Event: Poster session presented at International Conference on Algal Biorefinery, Kharagpur, India.
Main Research Area: Technical/natural sciences
Electronic versions:
14.pdf
Publication: Research - peer-review › Poster – Annual report year: 2013
Life Cycle Assessment of a brown seaweed-based third-generation biorefinery process

General information
State: Published
Organisations: Department of Environmental Engineering, Residual Resource Engineering
Pages: 1865-1868
Publication date: 2013

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Place of publication: Copenhagen
Publisher: ETA-Florence Renewable Energies
Main Research Area: Technical/natural sciences
Conference: EU BC&E 21st European Biomass Conference and Exhibition, Copenhagen, Denmark, 03/06/2013 - 03/06/2013
Source: dtu
Source-ID: u::9847
Publication: Research - peer-review › Article in proceedings – Annual report year: 2013

Life cycle assessment of biofuel production from brown seaweed in Nordic conditions

The use of algae for biofuel production is expected to play an important role in securing energy supply in the next decades. A consequential lifecycle assessment (LCA) and an energy analysis of seaweed-based biofuel production were carried out in Nordic conditions to document and improve the sustainability of the process. Two scenarios were analyzed for the brown seaweed (Laminaria digitata), namely, biogas production (scenario 1) and bioethanol + biogas production (scenario 2). Potential environmental impact categories under investigation were Global Warming, Acidification and Terrestrial Eutrophication. The production of seaweed was identified to be the most energy intensive step. Scenario 1 showed better performance compared to scenario 2 for all impact categories, partly because of the energy intensive bioethanol separation process and the consequently lower overall efficiency of the system. For improved environmental performance, focus should be on optimization of seaweed production, bioethanol distillation, and management of digestate on land.

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State: Published
Organisations: Department of Environmental Engineering, Residual Resource Engineering
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Journal: Bioresource Technology
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BFI (2017): BFI-level 2
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 5.94 SJR 2.191 SNIP 1.91
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 2.255 SNIP 1.908 CiteScore 5.47
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 2.41 SNIP 2.104 CiteScore 5.3
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 2.412 SNIP 2.503 CiteScore 5.97
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Microalgae Biorefinery - Industrial Symbiosis

General information
State: Published
Organisations: Department of Environmental Engineering, Residual Resource Engineering, Urban Water Engineering, National Food Institute, Division of Industrial Food Research, Kalundborg Kommune
Number of pages: 1
Publication date: 2013
Event: Poster session presented at Copenhagen Bioscience Conference: Cell Factories and Biosustainability, Denmark.
Main Research Area: Technical/natural sciences
Electronic versions: posterb.pdf
Source: PublicationPreSubmission
Source-ID: 100370841
Publication: Research - peer-review › Poster – Annual report year: 2014
Algal eating habits of phycologists attending the ISAP Halifax Conference and members of the general public

A short questionnaire was devised during the 4th ISAP Conference in Halifax (2011) to gather some information on the algal eating habits of the participants. Responses were also collected from random members of the general public in Galway and Copenhagen. Most phycologists had eaten algae before (93%), but few conference participants ate it more regularly than per month. Responses of the general public were similar. A probability model tested the likelihood of a participant eating algae. Neither age nor nationality significantly influenced this probability, although gender increased the probability of eating algae regularly by 9% if the participant was male (at the 90% confidence limit). As hypothesised, being a conference attendee highly significantly increased the probability of eating algae by 22%, in comparison with non-conference attendees (i.e. the general public). The type of phycological research studied also had a significant effect. Researchers working with macroalgae were 22% more likely to eat algae, whereas microalgal researchers were 15% less likely to eat algae on a monthly or more regular basis. The main reasons for eating algae by both groups were ‘taste’, followed by ‘other’ (undefined) reasons, whereas the main reason for not eating algae in both groups was a ‘lack of availability’. Phycologists also ate algae for the perceived ‘health benefits’ (36%), whereas few members of the general public chose this option (13%). Consumption of red seaweeds was most popular (60% of phycologists and 71% of the general public), with Porphyra spp. most commonly preferred. In total, 27 genera of macroalgae and microalgae were recorded as eaten by questionnaire participants.

General information
State: Published
Organisations: Department of Environmental Engineering, The Ryan Institute, J.E. Cairnes School of Business and Economics
Authors: Edwards, M. D. (Ekstern), Holdt, S. L. (Intern), Hynes, S. (Ekstern), Critchley, A. T. (Ekstern)
Pages: 627-633
Publication date: 2012
Main Research Area: Technical/natural sciences

Publication information
Journal: Journal of Applied Phycology
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BFI (2017): BFI-level 1
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 2.46
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 2.32
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): CiteScore 2.88
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): CiteScore 2.78
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): CiteScore 2.68
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): CiteScore 2.29
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 1
BFI (2008): BFI-level 1
Green macroalgae for biomitigation of nutrients, purification of biogas and energy production

General information
State: Published
Organisations: Department of Environmental Engineering, Section for Population Ecology and Genetics, Residual Resource Engineering
Authors: Holdt, S. L. (Intern), Galanidis, S. (Ekstern), Margarido Pargana, A. (Intern), Angelidaki, I. (Intern)
Number of pages: 1
Publication date: 2012
Main Research Area: Technical/natural sciences
Electronic versions:
2-Ulva Ulvaria poster-suho-final.pdf
Source: dtu
Source-ID: u::6590
Publication: Research › Poster – Annual report year: 2012

Microalgal Cultivation at Kalundborg Municipal Wastewater Treatment Facility

General information
State: Published
Organisations: Department of Environmental Engineering, Residual Resource Engineering, Kalundborg Kommune
Authors: Van Wagenen, J. (Intern), Møller, P. (Ekstern), Holdt, S. L. (Intern), De Francisci, D. (Intern), Angelidaki, I. (Intern)
Number of pages: 1
Publication date: 2012
Event: Poster session presented at Young Algaeneer Symposium, Wageningen, Netherlands.
Main Research Area: Technical/natural sciences
Electronic versions:
jvw_Wageningen_poster_slide1_suho.pdf
Source: PublicationPreSubmission
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Publication: Research - peer-review › Poster – Annual report year: 2012

Screening and Optimization of Case Specific Sustainable Mixotrophic Microalgal Medium

General information
State: Published
Organisations: Department of Environmental Engineering, Residual Resource Engineering
Authors: Podevin, M. (Intern), Borch, M. M. (Ekstern), De Francisci, D. (Intern), Holdt, S. L. (Intern), Angelidaki, I. (Intern), Møller, P. (Ekstern)
Number of pages: 1
Publication date: 2012
Event: Poster session presented at Young Algaeneer Symposium, Wageningen, Netherlands.
Main Research Area: Technical/natural sciences
Electronic versions:
Young Alganeers Presentation Final 1-02-13.pdf
Source: dtu
Source-ID: u::6893
Publication: Research - peer-review › Poster – Annual report year: 2013
Bioactive compounds in seaweed; functional food applications and legislation

Seaweed is more than the wrap that keeps rice together in sushi. Seaweed biomass is already used for a wide range of other products in food, including stabilising agents. Biorefineries with seaweed as feedstock are attracting worldwide interest and include low-volume, high value-added products and vice versa. Scientific research on bioactive compounds in seaweed usually takes place on just a few species and compounds. This paper reviews worldwide research on bioactive compounds, mainly of nine genera or species of seaweed, which are also available in European temperate Atlantic waters, i.e. Laminaria sp., Fucus sp., Ascophyllum nodosum, Chondrus crispus, Porphyra sp., Ulva sp., Sargassum sp., Gracilaria sp. and Palmaria palmata. In addition, Undaria pinnatifida is included in this review as this is globally one of the most commonly produced, investigated and available species. Fewer examples of other species abundant worldwide have also been included. This review will supply fundamental information for biorefineries in Atlantic Europe using seaweed as feedstock. Preliminary selection of one or several candidate seaweed species will be possible based on the summary tables and previous research described in this review. This applies either to the choice of high value-added bioactive products to be exploited in an available species or to the choice of seaweed species when a bioactive compound is desired. Data are presented in tables with species, effect and test organism (if present) with examples of uses to enhance comparisons. In addition, scientific experiments performed on seaweed used as animal feed are presented, and EU, US and Japanese legislation on functional foods is reviewed.

General information
State: Published
Organisations: Department of Environmental Engineering, Ocean Harvest Technology
Authors: Holdt, S. L. (Intern), Kraan, S. (Ekstern)
Pages: 543-597
Publication date: 2011
Main Research Area: Technical/natural sciences

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BFI (2016): BFI-level 1
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Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): CiteScore 2.32
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): CiteScore 2.88
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): CiteScore 2.78
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): CiteScore 2.68
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): CiteScore 2.29
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 1
BFI (2008): BFI-level 1
Cultivation of the green macroalgae Ulva lactuca and Ulvaria splendens for biofuels production

General information
State: Published
Organisations: Residual Resource Engineering, Department of Environmental Engineering, Technical University of Denmark
Authors: Angelidaki, I. (Intern), Galanidis, S. (Ekstern), Holdt, S. L. (Intern), Jørgensen, M. W. (Intern)
Publication date: 2011
Main Research Area: Technical/natural sciences
Electronic versions:
Ulva.pdf
Links:
http://www.isap2011-halifax.org/
Source: orbit
Source-ID: 278273
Publication: Research › Poster – Annual report year: 2011

High rate algal biomass production for food, biochemicals and Biofuels: An Indo-Danish collaboration project.

General information
State: Published
Organisations: Residual Resource Engineering, Department of Environmental Engineering, Technical University of Denmark, IIT Kharagpur, Indian Agricultural Research Institute, SPRTC, India
Publication date: 2011
Main Research Area: Technical/natural sciences
Electronic versions:
isap-Angelidaki-et.pdf
Source: orbit
Source-ID: 282861
Publication: Research › Conference abstract for conference – Annual report year: 2011

Tang kan både dyrkes og fanges: Billeder i Fiskertidende den 16. juni 2011

General information
State: Published
Organisations: Department of Environmental Engineering
Authors: Holdt, S. L. (Intern)
Publication date: 2011

Publication information
Original language: English
Main Research Area: Technical/natural sciences
**Nutrient reduction in aquaculture waste by macroalgae production**

Danish marine finfish aquaculture wants to increase production and follow the trend of increasing world wide demand for finfish, but restrictions are based on environmental concerns. The demand on seaweeds are also increasing on the market due to its content of vitamins, minerals, gelling agents etc. as well as its potential use for environmental friendly biofuel. Furthermore, seaweeds (macroalgae) assimilate nutrients and can therefore bioremediate wastes in seawater. Linking finfish and seaweed aquaculture together, the seaweed can convert the nutrient waste from the fed aquaculture production into a valuable product and when harvested the environmental footprint from the finfish production will be smaller. This led to the aim of this Ph.D.-project: “Nutrient reduction in aquaculture waste by macroalgae production”. In this study the three red macroalgae containing gelling agents; Chondrus crispus, Furcellaria lumbricalis and Gracilaria vermiculophylla, were investigated as candidates for polyculture acting as biofilters near two fish farms in the inner Danish waters. In addition, the biofilter potential of C. crispus was investigated in outdoor tank cultures receiving fish effluent or seawater. Furthermore, the sporation method was examined on C. crispus to only get the most valuable life phase and reduce labor intensity. Finally, thalli of C. crispus were cultivated in a bubble column photobioreactor in the laboratory to examine growth and open up the “black box” of growth in between inocula- and end-biomass with on-line growth measurements. In the field near the two fish farms, the highest specific growth rates were C. crispus 0.018±0.006 d-1, F. lumbricalis 0.011±0.004 d-1 and G. vermiculophylla 0.039±0.007 d-1. Results showed a small increase in biomass and a decrease in the specific growth rates of the three macroalgae, while the epibios biomass increased during the deployment periods. Decrease of specific growth rates of C. crispus with distance and increase with feed use underline the importance of the nutrient source originating from the fish farm for algal growth. The slow growth of the investigated macroalgal species, however, makes the production of algal biomass too small to reduce the nutrient waste from the fish farms significantly. The biomass of C. crispus cultivated in outdoor tanks reduced nutrients in the received fish effluent and seawater. The biomass increased up to 110 % during 27 days of experiment with specific growth rates of 0.03 d-1 reached in the flow-through cultures and 0.01 d-1 in the batch cultures. Only the seaweed in the flow-through culture with fish effluent had nitrogen content higher than the critical level for growth and furthermore were not bleached, which indicated non-limited growth with respect to nutrients. Whole thalli of C. crispus cultivated in the photobioreactor with nonlimiting temperature, light and carbon dioxide supply reached a specific growth rate of 0.095 d-1 and contamination was kept at a low level, while fragments of freshly formed thalli reached growth rates of 0.12 d-1 without contaminants and epiphytes. On-line data of carbon dioxide addition from the closed system reflected photosynthetic activity, and these results revealed lag-phases and existence of several exponential growth phases in one of the experiments. Germination of the most valuable tetraspores of C. crispus in the photobioreactor and in the field was successful. The specific growth rate of sporelings in the photobioreactor was 0.065 d-1 and sporelings reached an average length of 1.1±0.1 cm in 119 days. In the field, sporelings reached a maximum length of 1.5 cm with low growth of epibios during four months. In conclusion, the investigated species either grow too slowly to be used for polyculture or as a biofilter near Danish fish farms and/or they cannot be sold as a product due to the high degree of epibios coverage. The bubble column photobioreactor method is well suited to characterize the growth of C. crispus and the on-line data identifies the different growth phases during an experiment. This identification is not possible in the commonly used method in which specific growth rate depends on beginning and end biomass. Further studies could give more information about variables importance for macroalgal growth. However, this method is expensive and needs attention and not suitable for large-scale production of C. crispus unless the produced biomass is for, e.g., high value secondary metabolites. The species Saccharina latissima has in recent studies showed applicability as the future seaweed for polyculture or biofilter in Danish offshore marine fish farming with well known sporation method, high growth rate and biomass production and low epibios. However, the value of the seaweed biomass is low, but the bioremediation effect is the most important right now for the offshore marine fish farmers in order to maintain their licenses to produce finfish.
Algal cultivation: a "new" resource for biorefinery

General information
State: Published
Organisations: Department of Environmental Engineering
Authors: Holdt, S. L. (Intern)
Publication date: 2010
Main Research Area: Technical/natural sciences

Publication information
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Original language: English
Source: orbit
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Publication: Research › Conference abstract in journal – Annual report year: 2010

Phenolic composition and in vitro antioxidant activities of selected species of seaweeds from Danish coast.

General information
State: Published
Organisations: National Food Institute, FoodDTU
Authors: Farvin, S. (Intern), Holdt, S. (Intern), Jacobsen, C. (Intern)
Publication date: 2010
Event: Abstract from American oil chemists society Annual meeting and Expo, Phoenix, Arizona, USA.
Main Research Area: Technical/natural sciences
Source: orbit
Source-ID: 265294
Publication: Research - peer-review › Conference abstract for conference – Annual report year: 2010

Tang - sundt for krop og klima

General information
State: Published
Organisations: Section for Aquatic Process and Product Technology, National Institute of Aquatic Resources
Authors: Holdt, S. (Intern)
Pages: 1
Publication date: 2009
Main Research Area: Technical/natural sciences

Publication information
Journal: SeafoodCircle Nyhedsbrev 12
Issue number: 12
Original language: Danish
Electronic versions:
SeafoodCircle - Faktablad 12-2009 - Tang - sundt for krop og klima.pdf
Source: orbit
Source-ID: 253252
Publication: Communication › Journal article – Annual report year: 2009

Rejection of unsuitable substrata a potential driver of aggregated settlement in the barnacle Balanus improvisus

General information
State: Published
Organisations: University of Gothenburg, University of Copenhagen
Authors: Berntsson, K. M. (Ekstern), Jonsson, P. R. (Ekstern), Larsson, A. (Ekstern), Holdt, S. L. (Intern)
Pages: 199-210
Publication date: 2004
Main Research Area: Technical/natural sciences

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Journal: Marine Ecology Progress Series
Volume: 275
Projects:

**Protein valorization through informatics, hydrolysis, and separation**
WP leader on the industrialization part of proteins from seaweed

National Food Institute

Research Group for Bioactives – Analysis and Application

Research Group for Gut Microbiology and Immunology

Period: 01/09/2017 → 31/08/2021
Number of participants: 4
Acronym: PROVIDE
Project participant:
Holdt, Susan Løvstad (Intern)
Jacobsen, Charlotte (Intern)
Hansen, Egon Bech (Intern)
García Moreno, Pedro Jesús (Intern)

**Greenlandic seaweeds for human consumption**
PhD project
National Food Institute
Research Group for Bioactives – Analysis and Application

Research Group for Analytical and Predictive Microbiology
Period: 01/05/2017 → 30/04/2020
Number of participants: 4
Number of related Ph.D. students: 1
Project participant:
Holdt, Susan Løvstad (Intern)
Kreissig, Katharina Johanna (Intern)
Hansen, Lisbeth Truelstrup (Intern)
Jacobsen, Charlotte (Intern)

WP leader of the food and feed safety issues
National Food Institute
Research Group for Bioactives – Analysis and Application
Period: 01/04/2017 → 31/03/2021
Number of participants: 1
Acronym: Tang.nu
Project participant:
Holdt, Susan Løvstad (Intern)

Danish Seaweed Organisation
Platform for the Danish seaweed Companies to go on the export market
National Food Institute
Research Group for Bioactives – Analysis and Application
Period: 01/01/2017 → …
Number of participants: 1
Acronym: DSO
Project participant:
Holdt, Susan Løvstad (Intern)

Valorization of red seaweed biomasses towards future sustainability (VALSEA), Multiextraction of Bioactive Compounds from Macroalgae
National Food Institute
Period: 01/02/2016 → 21/03/2019
Number of participants: 3
Phd Student:
Naseri, Alireza (Intern)
Supervisor:
Holdt, Susan Løvstad (Intern)
Main Supervisor:
Jacobsen, Charlotte (Intern)

Financing sources
Source: Internal funding (public)
Name of research programme: Samfinansieret - Andet
Project: PhD

Optimization of processes, yield and biomass composition in large scale macroalgal cultivation in open ocean environments
National Food Institute
Period: 15/01/2016 → 14/01/2019
Number of participants: 4
Phd Student: Grandorf Bak, Urd (Intern)
Supervisor: Gregersen, Olavur (Ekstern) Holdt, Susan Løvstad (Intern)
Main Supervisor: Jacobsen, Charlotte (Intern)

Financing sources
Source: Internal funding (public)
Name of research programme: Industrial PhD
Project: PhD

Valorization of red seaweed biomasses towards future sustainability (VALSEA), Multiextraction of Bioactive Compounds from Macroalgae
The aim of this applied research project is to better utilize the valuable compounds in seaweed and thereby achieve a higher return, since at present, Danish and international companies only extract specific stabilizing agents/ingredients from seaweed for use in various food and consumer products, and several valuable compounds go to waste. In this project the National Food Institute will use its expertise within seaweed research in cooperation with four Danish companies; CP Kelco, GEA Niro, Third Wave Nutrition and Nordisk Tang by Endelave.
Not only carrageenan or furcellaran as single extraction, but a future multi-extraction of valuable proteins, natural food colours and antioxidants will turn waste into value, to be used in e.g. protein shakes.
The research include the entire value chain from the extraction, drying of the extracted products such as protein, testing and application for ready products, and includes red seaweed species to be researched such as: Eucheuma spinosum, Furcellaria lumbricalis and Palmaria palmata for their different compositions and applications.
DTU Food partners are Charlotte Jacobsen, Susan L. Holdt and Alireza Naseri

National Food Institute
Research Group for Bioactives – Analysis and Application
Period: 01/01/2016 → 31/12/2019
Number of participants: 3
Acronym: VALSEA
Project participant: Naseri, Alireza (Intern)
Project Manager, academic: Jacobsen, Charlotte (Intern)
Project Coordinator: Holdt, Susan Løvstad (Intern)

Relations
Related projects:
Valorization of red seaweed biomasses towards future sustainability (VALSEA), Multiextraction of Bioactive Compounds from Macroalgae
Project

TangMatch International
Preparing the Danish SME’s for meeting the International Seaweed World at the 22nd International Seaweed Symposium (ISS) in Copenhagen, June, 2016. This included a matchmaking session with B2B at the ISS

National Food Institute
Research Group for Bioactives – Analysis and Application
Period: 01/08/2015 → 31/07/2016
Number of participants: 1
Acronym: TangMatch 2
Project participant: Holdt, Susan Løvstad (Intern)
**High value protein products in seaweed**

The overall aim of the project is to develop new technologies that will ensure full utilization of the seaweed raw materials used for carrageenan production. More specifically, the aim is to develop new technologies to extract proteins from the seaweed either before or after extraction of carrageenan. Different mechanical and enzymatic technologies will be evaluated. The protein composition and the quality of the carrageenan fraction after extraction of proteins will be determined. The process will be scaled up to pilot scale if promising results are obtained in lab scale.

National Food Institute

Research Group for Bioactives – Analysis and Application

Research Group for Food Production Engineering

**Period:** 20/10/2014 → 31/01/2016

**Number of participants:** 5

**Acronym:** HIT

**Project participant:**

Jacobsen, Charlotte (Intern)
Holdt, Susan Løvstad (Intern)
Naseri, Alireza (Intern)
Kryger, Karsten (Intern)
Jessen, Flemming (Intern)

**Financing sources**

**Source:** Private funding (private)

**Name of research programme:** KP Pedersen og Hustru Fond

**Amount:** 800,000.00 Danish Kroner

TANGMATCH

National Food Institute

Research Group for Bioactives – Analysis and Application

Division of Risk Assessment and Nutrition

**Period:** 01/09/2014 → 31/08/2015

**Number of participants:** 4

**Acronym:** TANGMATCH

**Project participant:**

Holdt, Susan Løvstad (Intern)
Grandorf Bak, Urd (Intern)
Kryger, Karsten (Intern)
Jarlbæk, Henrik (Intern)

**Financing sources**

**Source:** Private funding (private)

**Name of research programme:** KP Pedersen og Hustru Fond

**Amount:** 323,000.00 Danish Kroner

Quality manual for producing Laminaria species for the Asian market

National Food Institute

Division of Industrial Food Research

**Period:** 31/01/2014 → 01/10/2014

**Number of participants:** 1

**Project participant:**

Holdt, Susan Løvstad (Intern)

Algal biofilter optimization near fish farm

Department of Environmental Engineering
Period: 01/09/2012 → 29/02/2016
Number of participants: 6
Phd Student:
Silva Marinho, Goncalo (Intern)
Supervisor:
Holdt, Susan Løvstad (Intern)
Main Supervisor:
Angelidaki, Irini (Intern)
Examiner:
Karakashev, Dimitar Borisov (Intern)
Bruhn, Annette (Ekstern)
Stanley, Michele Suzanne (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Institut stipendie (DTU) Samf.
Project: PhD

Kombinationsopdræt af havbrugfisk, tang, muslinger til foder og konsum
National Food Institute
Research Group for Bioactives – Analysis and Application
Department of Environmental Engineering
Residual Resource Engineering
Period: 15/12/2011 → 01/04/2015
Number of participants: 3
Acronym: Kombiopdræt
Project participant:
Holdt, Susan Løvstad (Intern)
Silva Marinho, Goncalo (Intern)
Angelidaki, Irini (Intern)

Financing sources
Source: Public research programme (public)
Name of research programme: GUDP
Amount: 14,600,000.00 Danish Kroner
Project

Activities:

Danish Seaweed Organisation (DSO) (External organisation)
Period: 2017 → …
Susan Løvstad Holdt (Chairman)
National Food Institute
Research Group for Bioactives – Analysis and Application

Description
Board member, treasurer of the Danish Seaweed Organisation (DSO)
Degree of recognition: National

Related external organisation

Danish Seaweed Organisation (DSO)
Activity: Membership › Board duties in companies, associations, or public organisations

EU CEN 454 standardisation of algae (External organisation)
Period: 2017 → …
Susan Løvstad Holdt (Chairman)
National Food Institute
Research Group for Bioactives – Analysis and Application

Description
Chair of the national mirror committee of the EU CEN 454 standardisation of algae
Degree of recognition: International

Related external organisation
EU CEN 454 standardisation of algae
Activity: Membership › Membership of commitees, commissions, boards, councils, associations, organisations, or similar

EUREKA expert (External organisation)
Period: 2017
Susan Løvstad Holdt (Chairman)
National Food Institute
Research Group for Bioactives – Analysis and Application

Description
EUREKA Expert (invited member of the EUREKA expert database) to evaluate project proposals
Degree of recognition: International

Related external organisation
EUREKA expert
Activity: Membership › Membership in review committee

Journal of Applied Phycology (Journal)
Period: 2017
Susan Løvstad Holdt (Reviewer)
National Food Institute
Research Group for Bioactives – Analysis and Application

Description
Invited as guest editor of the issue on the proceedings of the International Seaweed Symposium, Copenhagen, June 2016
Degree of recognition: International

Related journal
Journal of Applied Phycology
0921-8971
Central database
Activity: Research › Peer review of manuscripts

Adsorption of microplastics to the edible Fucus vesiculosus and possible wash off before food application
Period: 22 Jun 2017
Nanna B. Hartmann (Speaker)
Clara G. Villaro (Speaker)
Ida D.W. Koch (Speaker)
Kasper B. Sundbæk (Speaker)
Niclas S. Rasmussen (Speaker)
Susan Løvstad Holdt (Speaker)
National Food Institute
The growing demand for food accessibility, due to rapidly growing population of the world, has raised the interest of macroalgae as a food source also in the Western world. However, this combined with increased food awareness trigger a concern that accumulated microplastics in the oceans might pollute the seaweed and influence food safety and thereby applicability. One of the most common types of seaweed in Denmark is bladder wrack, Fucus vesiculosus (FC), and this specimen is also popular for the use in e.g. pesto and flour in Denmark. This study investigated if fluorescent polystyrene (PS) microplastic particles (diameter: 20 μm) adsorb to the macroalga FC and if they can be washed off afterwards with filtered seawater.

Degree of recognition: International

Documents:

ISAP_2017_abstract_Hartmann et al-Microplastic on Fucus

Seaweed at stake
Period: 21 Jun 2017
Susan Løvstad Holdt (Organizer)
National Food Institute
Research Group for Bioactives – Analysis and Application
Degree of recognition: International

Related event

Seaweed at stake: Seaweed stakeholder meeting
21/06/2017 → 21/06/2017
Nantes, France
Activity: Attending an event › Participating in or organising workshops, courses, seminars etc.

Antioxidant composition and activity of seaweed Saccharina latissima: a seasonal perspective
Period: 19 Jun 2017
Goncalo Silva Marinho (Speaker)
Ann-Dorit Moltke Sørensen (Speaker)
Hamed Safafar (Speaker)
Anja H. Pedersen (Speaker)
Susan Løvstad Holdt (Speaker)
National Food Institute
Research Group for Bioactives – Analysis and Application
Degree of recognition: International

Description
Safety concerns regarding reported toxicity of artificial antioxidants lead the search for novel natural antioxidants. In this context, seaweeds have been receiving increasing attention as a promising source of antioxidants such as phenolic compounds (e.g. phenolic acids and flavonoids), carotenoids (e.g. fucoxanthin and β-carotene), and phycobiliproteins. Nevertheless, seaweed composition generally presents marked seasonal variations. The present study aimed at evaluating seasonal variations in the antioxidant composition and activity of sugar kelp, Saccharina latissima, cultivated at two different sites; in close proximity to a blue mussel and rainbow trout farm (IMTA), and at a reference/control site (REF), outside Horsens fjord, Denmark.

Degree of recognition: International

Documents:

Abstract-ISAP 2017-Marinho et al_FINAL

Related external organisation
Is nitrogen-to-protein conversion factor for seaweed dependent on season?

Period: 19 Jun 2017

Goncalo Silva Marinho (Speaker)
Susan Løvstad Holdt (Speaker)

National Food Institute
Research Group for Bioactives – Analysis and Application

Description
Recently an effort has been made to establish nitrogen-to-protein conversion factors specific for seaweeds, as the tradition conversion factor of 6.25 overestimates their protein content. Nevertheless, potential seasonal variation of this conversion factor has not yet been considered. This paper evaluates the seasonal nitrogen budget of Saccharina latissima and discusses the importance of more specific nitrogen-to-protein conversion factors, also taking season into account.

Degree of recognition: International
Documents:
Abstract_ISAP 2017-Marinho and Holdt-Nitrogen-to-protein-factor

Related external organisation
University of Nantes
France
Activity: Talks and presentations › Conference presentations

EU COST Association (External organisation)
Period: 2016 → …

Susan Løvstad Holdt (Chairman)
National Food Institute
Research Group for Bioactives – Analysis and Application

Description
External Expert in the remote evaluation, EU COST Association
Degree of recognition: International

Related external organisation
EU COST Association
Activity: Membership › Membership of research networks or expert groups

Norwegian project MACROSEA (External organisation)
Period: 2016 → …

Susan Løvstad Holdt (Chairman)
National Food Institute
Research Group for Bioactives – Analysis and Application

Description
External scientific board member of the national Norwegian project MACROSEA
Degree of recognition: International

Related external organisation
Norwegian project MACROSEA
Activity: Membership › Membership of research networks or expert groups

The United States - Israel Binational Agricultural Research and Development Fund (External organisation)
Period: 2016
Susan Løvstad Holdt (Chairman)
National Food Institute
Research Group for Bioactives – Analysis and Application

Description
External reviewer of The United States - Israel Binational Agricultural Research and Development Fund
Degree of recognition: International

Related external organisation
The United States - Israel Binational Agricultural Research and Development Fund
Activity: Membership › Membership in review committee

Seaweed Matchmaking
Period: 21 Jun 2016
Susan Løvstad Holdt (Speaker)
National Food Institute
Research Group for Bioactives – Analysis and Application
Degree of recognition: International

Related event
Seaweed Matchmaking: Danish SME's pitches their company and B2B meeting
21/06/2016 → 21/06/2016
Copenhagen, Denmark
Activity: Talks and presentations › Talks and presentations in private or public companies and organisations

Seaweed Matchmaking
Period: 21 Jun 2016
Susan Løvstad Holdt (Organizer)
National Food Institute
Research Group for Bioactives – Analysis and Application

Description
Preparing and having the Danish SME's to pitch at the International Seaweed Symposium, Copenhagen, June 2016
Degree of recognition: International

Related event
Seaweed Matchmaking: Danish SME's pitches their company and B2B meeting
21/06/2016 → 21/06/2016
Copenhagen, Denmark
Activity: Attending an event › Participating in or organising workshops, courses, seminars etc.

22nd International Seaweed Symposium
Susan Løvstad Holdt (Organizer)
National Food Institute
Research Group for Bioactives – Analysis and Application

Description
Chair of the local organising committee
Degree of recognition: International

Related event
22nd International Seaweed Symposium
19/06/2016 → 24/06/2016
Copenhagen, Denmark
Activity: Attending an event › Participating in or organising a conference

**International Seaweed Association Council (ISAC) (External organisation)**
Period: 19 Jun 2016 → …
Susan Løvstad Holdt (Chairman)
National Food Institute
Research Group for Bioactives – Analysis and Application

**Description**
Elected as Secretary General of the International Seaweed Association Council (ISAC)
Degree of recognition: International

**Related external organisation**
International Seaweed Association Council (ISAC)
Activity: Membership › Membership of committees, commissions, boards, councils, associations, organisations, or similar

**COST ACTION FA1406 within Food and Agriculture (External organisation)**
Period: 2015 → …
Susan Løvstad Holdt (Chairman)
National Food Institute
Research Group for Bioactives – Analysis and Application

**Description**
Management Committee member assigned by the COST /the COST National Coordinators (usually Ministry). More specifically for the COST ACTION FA1406 within Food and Agriculture COST Action: Advancing knowledge on seaweed growth and development
Degree of recognition: International

**Related external organisation**
COST ACTION FA1406 within Food and Agriculture
Activity: Membership › Membership in review committee

**Danish complaints board of Nature and Environment (External organisation)**
Period: 2015 → …
Susan Løvstad Holdt (Chairman)
National Food Institute
Research Group for Bioactives – Analysis and Application

**Description**
Appointed member of the Danish complaints board of Nature and Environment
Degree of recognition: National

**Related external organisation**
Danish complaints board of Nature and Environment
Activity: Membership › Membership of committees, commissions, boards, councils, associations, organisations, or similar

**National Food Institute (Organisational unit)**
Period: 2015 → …
Susan Løvstad Holdt (Chairman)
National Food Institute
Research Group for Bioactives – Analysis and Application

**Description**
WiES: Committee member of the network at DTU: Women in Engineering Science
Degree of recognition: Local

Related organisation

National Food Institute (Organisational unit)
Holdt, S. L. (Chairman)
2015 → ...
Activity: Membership › Membership of committees, commissions, boards, councils, associations, organisations, or similar

Scandinavian Culture Collection of Algae and Protozoa (SCCAP) (External organisation)
Period: 2015 → 2016
Susan Løvstad Holdt (Chairman)
National Food Institute
Research Group for Bioactives – Analysis and Application

Description
Member of the board of directors for the Scandinavian Culture Collection of Algae and Protozoa (SCCAP). Now closed-moved to Norway
Degree of recognition: National

Related external organisation

Scandinavian Culture Collection of Algae and Protozoa (SCCAP)
Activity: Membership › Board duties in companies, associations, or public organisations

TEACH FOOD seminar
Susan Løvstad Holdt (Organizer)
National Food Institute
Research Group for Bioactives – Analysis and Application

Related event

TEACH FOOD seminar: seminar for DTU FOOD teachers
29/10/2015 → 30/10/2015
Hvalsø, Denmark
Activity: Attending an event › Participating in or organising workshops, courses, seminars etc.

Current Nutrition & Food Science (Journal)
Period: 2014
Susan Løvstad Holdt (Reviewer)
National Food Institute
Research Group for Bioactives – Analysis and Application

Description
Peer-review
Degree of recognition: International

Related journal

Current Nutrition & Food Science
1573-4013
Scopus rating (2016): CiteScore 0.58 SJR 0.266 SNIP 0.322, Web of Science (2015): Indexed yes
Central database
Activity: Research › Peer review of manuscripts

Safety and Health Effects of Aquatic Food
Period: 2014 → …
Susan Løvstad Holdt (Guest lecturer)
National Food Institute
Research Group for Bioactives – Analysis and Application

Description
Lecture on seaweed bioactive compounds, analyses and application
Degree of recognition: Regional

Related organisation
Safety and Health Effects of Aquatic Food
Holdt, S. L. (Guest lecturer)
2014 → …
Activity: Talks and presentations › Guest lectures, external teaching and course activities at other universities

DTU Sustain Conference 2014
Period: 17 Dec 2014
Susan Løvstad Holdt (Speaker)
National Food Institute
Division of Industrial Food Research
Documents:
Sustain DTU conf-IMTA-SLHoldt et al-abstract
Links:
http://prezi.com/pho94laaoj7/?utm_campaign=share&utm_medium=copy&rc=ex0share

Related event
DTU Sustain Conference 2014
17/12/2014 → 17/12/2014
Lyngby, Denmark
Activity: Talks and presentations › Conference presentations

4th Nordic Seaweed Conference
Susan Løvstad Holdt (Speaker)
National Food Institute
Division of Industrial Food Research
Documents:
Grenaa-Amino acid in seaweed IMTA-Holdt et al 2014-final

Related event
4th Nordic Seaweed Conference
08/10/2014 → 09/10/2014
Grenaa, Denmark
Activity: Talks and presentations › Conference presentations

5th Congress of the International Society for Applied Phycology
Period: 22 Jun 2014 → 27 Jun 2014
Susan Løvstad Holdt (Speaker)
National Food Institute
Division of Industrial Food Research

Related event
5th Congress of the International Society for Applied Phycology
22/06/2014 → 27/06/2014
5th Congress of the International Society for Applied Phycology
Period: 22 Jun 2014 → 27 Jun 2014
Susan Løvstad Holdt (Speaker)
National Food Institute
Division of Industrial Food Research
Documents:
ISAP2014 Sugarkelp as biofilter-GSMarinho et al_final!

Related event

5th Congress of the International Society for Applied Phycology
22/06/2014 → 27/06/2014
Sydney, Australia
Activity: Talks and presentations › Conference presentations

The Commercial IMTA and future seaweed biofilter potential in Denmark
Period: 22 Jun 2014 → 27 Jun 2014
Susan Løvstad Holdt (Invited speaker)
National Food Institute
Division of Industrial Food Research
Documents:
The Commercial IMTA and future seaweed biofilter potential-SLHoldt-final

Related event

5th Congress of the International Society for Applied Phycology
22/06/2014 → 27/06/2014
Sydney, Australia
Activity: Talks and presentations › Conference presentations

Botanica Marina (Journal)
Period: 2013
Susan Løvstad Holdt (Reviewer)
National Food Institute
Research Group for Bioactives – Analysis and Application
Description
Peer-reviewer
Degree of recognition: International

Related journal

Botanica Marina
Local database
Activity: Research › Peer review of manuscripts

European Research Council, Swiss National Science Foundation (SNSF), (External organisation)
Period: 2013
Susan Løvstad Holdt (Chairman)
National Food Institute
Research Group for Bioactives – Analysis and Application

Description
External reviewer of European Research Council, Swiss National Science Foundation (SNSF), Bern, Switzerland
Degree of recognition: International

Related external organisation

European Research Council, Swiss National Science Foundation (SNSF),
Activity: Membership › Membership in review committee

Journal of Aquatic Food Product Technology (Journal)
Period: 2013
Susan Løvstad Holdt (Reviewer)
National Food Institute
Research Group for Bioactives – Analysis and Application

Description
Peer-reviewer
Degree of recognition: International

Related journal

Journal of Aquatic Food Product Technology
1049-8850
BFI (2017): BFI-level 1, Scopus rating (2016): CiteScore 0.59 SJR 0.268 SNIP 0.582, ISI indexed (2013): ISI indexed yes, Web of Science (2017): Indexed Yes
Central database
Activity: Research › Peer review of manuscripts

Tang og multitrofisk produktion
Period: 6 Nov 2013
Susan Løvstad Holdt (Invited speaker)
National Institute of Aquatic Resources
Department of Environmental Engineering
National Food Institute
Residual Resource Engineering

Related event

ATV Temamøde Marin akvakultur: Perspektiver og potentialer
06/11/2013 → 06/11/2013
Kgs. Lyngby, Denmark
Activity: Talks and presentations › Conference presentations
Innovations konference
Period: 12 Sep 2013
Susan Løvstad Holdt (Invited speaker)
National Institute of Aquatic Resources
Department of Environmental Engineering
National Food Institute
Residual Resource Engineering

Description
Presented: Tang som ressource - mulighed for udvikling og produktion af ingredienser.

Fødevareingredienser - et dansk væksteventyr
Sundhed, Fødevareforsyning, Bæredygtighed, Fødevaresikkerhed

Related event
Innovations konference: Fødevareingredienser- et dansk væksteventyr
12/09/2013 → 12/09/2013
Copenhagen, Denmark
Activity: Talks and presentations › Conference presentations

International Conference on Algal Biorefinery
Period: 10 Jan 2013
Susan Løvstad Holdt (Participant)
Department of Environmental Engineering

Description
ICAB 2013
International Conference on Algal Biorefinery: A Potential Source of Food, Feed, Biochemicals, Biofuels and Biofertilizers
Links:
http://www.icab2012bt.iitkgp.ernet.in/icab/

Related event
International Conference on Algal Biorefinery: A Potential Source of Food, Feed, Biochemicals, Biofuels and Biofertilizers
10/01/2013 → 12/01/2013
Kharagpur, India
Activity: Attending an event › Participating in or organising a conference

Food Chemistry (Journal)
Period: 2012
Susan Løvstad Holdt (Reviewer)
National Food Institute
Research Group for Bioactives – Analysis and Application

Description
Peer-reviewer
Degree of recognition: International

Related journal
Food Chemistry
0308-8146
Web of Science (2017): Indexed Yes
Central database
Activity: Research › Peer review of manuscripts
New Uses and Possibilities for Seaweed
Period: 26 Sep 2012 → 27 Sep 2012
Susan Løvstad Holdt (Invited speaker)
National Institute of Aquatic Resources
Department of Environmental Engineering
National Food Institute
Residual Resource Engineering

Related event
Value Added Seafood Conference
26/09/2012 → 27/09/2012
London, United Kingdom
Activity: Talks and presentations › Conference presentations

Applied Marine Biology
Period: 2011 → …
Susan Løvstad Holdt (Guest lecturer)
National Food Institute
Research Group for Bioactives – Analysis and Application

Description
Supervisor for teams making a poster within a seaweed topic
Degree of recognition: Regional

Related external organisation
Copenhagen University
Activity: Talks and presentations › Guest lectures, external teaching and course activities at other universities

Applied Phycology
Period: 2011 → …
Susan Løvstad Holdt (Guest lecturer)
National Food Institute
Research Group for Bioactives – Analysis and Application

Description
Giving a lecture on bioactive compounds in seaweed and applications
Degree of recognition: Regional

Related external organisation
University of Copenhagen
Copenhagen, Denmark
Activity: Talks and presentations › Guest lectures, external teaching and course activities at other universities

Biomass & Bioenergy (Journal)
Period: 2011
Susan Løvstad Holdt (Reviewer)
National Food Institute
Research Group for Bioactives – Analysis and Application

Description
Peer-reviewer
Degree of recognition: International
Related journal

Biomass & Bioenergy
0961-9534
Central database
Activity: Research › Peer review of manuscripts

Marine Aquaculture
Period: 2011 → ...
Susan Løvstad Holdt (Guest lecturer)
National Food Institute
Research Group for Bioactives – Analysis and Application
Description
Lecture on seaweed cultivation
Degree of recognition: National

Related organisation

Marine Aquaculture
Holdt, S. L. (Guest lecturer)
2011 → ...
Activity: Talks and presentations › Guest lectures, external teaching and course activities at other universities